NON-TYPHOON WIND CONDITIONS AT HONG KONG'S WAGLAN ISLAND

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1. Introduction

Waglan Island, located approximately 5 km southeast of Hong Kong Island, has been used for the collection of long-term wind data since December 1952. Due to its location, relative lack of development, and the fact that it is essentially an isolated hill with relatively uninterrupted exposure to winds, data collected at Waglan Island is considered to be representative of winds approaching the Hong Kong region. Over the years, anemometers have been erected in a variety of locations on the southern-most of Waglan's two islands, as presented in Table 1. The Hong Kong wind climate has been studied previously through analysis of Waglan Island wind records by Chen (1975), Melbourne (1984), Davenport et al. (1984) and Ng (1997), which obviously do not include a significant portion of the records which are now available.

In this study, a wind tunnel test was undertaken to correct wind records for position and topographic effects for each anemometer location in Table 1. These were subsequently applied to the non-typhoon wind data collected at Waglan Island to determine the probability distribution of directional wind speed at the so-called gradient height above Waglan Island. The experimental results were also compared with results from a numerical simulation.

2. The Wind Tunnel Study

The wind velocity profile and wind turbulence characteristics generated in the wind tunnel for the Waglan Island model tests were scaled to simulate strong non-typhoon winds approaching the site over a so-called General Terrain, in accordance with the HKSAR Building Department's Practice Note for Authorized Persons and Registered Structural Engineers 150 (PNAP 150). The current practice calls for power law profiles for both speed ($\alpha = 0.19$) and turbulence intensity ($\alpha = -0.26$), and a gradient height of 200 m above MSL. Mean wind speed profile, turbulence intensity profile, and PSD for General Terrain according to PNAP 150 simulation are presented in Figure 1.

In the current study, a 1:400 scale model of Waglan Island was tested to determine directional correction factors relating anemometer wind speeds to equivalent gradient wind speeds for the various anemometer locations presented in Table 1. Measurements were taken at 22.5° intervals for the full 360° azimuth using a hotwire anemometer, relating the mean wind speed at each anemometer location and height to the mean speed of the approaching wind at 200 m. However, measurements were not taken for the anemometer location used during the period of 1964 to 1966, as the records obtained during that period are considered to be adversely affected by the mounting location of the anemometer.

Position correction factors for each anemometer location, excluding position 2, are presented in Figure 2. Although the results of Melbourne (1984) were referred to a height of 50 m, those in Figure 2 compare well on a qualitative basis at the very least. For the anemometer site used in the period of 19/12/1971 to 25/4/1993, a significant reduction in measured wind speed would be expected for winds from the east-south-east, whereas southerly winds would very nearly be equal to the so-called gradient wind-speed.

Certainly, the current anemometer location appears to be much less affected than its predecessors, thanks mainly to its additional height. Model wind speed measurements referred to the same approach speeds, taken at approximately the centroid of the anemometer sites, and at 200 m above MSL, are also presented in Figure 2. It can be seen that the topography of Waglan Island has the most significant effect on wind records obtained at the current station. The periodic features of the correction factors at 200 m can be attributed to the approach wind being more or less parallel to either the island's "major axis" (for northerly and southerly winds) or its "minor axis" (for easterly and westerly winds).

Using wind tunnel measurements, corrections were made to the hourly mean wind speed data to a height of 200 metres, the gradient height prescribed in PNAP 150 for General Terrain, to determine the probability distribution of wind speed and direction at the so-called gradient height over Waglan Island. This distribution is presented in Figure 3a, which indicates that prevailing and strong non-typhoon winds approaching Hong Kong occur mainly from northerly, easterly and south-westerly directions. Although containing an additional 15 years of wind records, including the period of operation of automatic weather stations from 22/8/1989 to present, there are very similar trends between Figure 3a and Figure 3b (from Davenport et al. (1984)).

3. CFX Study

CFX is a commercially available computational fluid dynamics software package based on finite volume formulation and able to handle highly distorted surface calculations. The computational domain was set up such that it was spanned by 97 × 134 surface data points with a height resolution of 10 m, and both the north and south island of Waglan Island were included. Nodes were specially constructed on the four anemometer sites studied to reduce the interpolation error during the data extraction process. The upstream boundary condition was defined as the previously discussed PNAP 150 General Terrain while other boundaries, including the side-walls, downstream and top boundaries, were specified as open, thereby permitting disturbances to propagate in and out of the domain freely and without reflection. The lower boundary allowed different kinds of use, sea or ground for example, and consequently different surface momentum fluxes. The sea surface was simulated by a free-slip boundary to maintain the upstream wind profiles. The ground surface was defined as a no-slip boundary with an effective roughness length of $z_0 = 0.001$ m, ie for a large, relatively calm expanse of water. CFX performs steady state simulation with the total integration time varying with wind direction, and the physical time step was equal to 10s. The convergence criteria were defined as the RMS residual of all dependent variables less than 0.001.

Anemometer correction factors determined through numerical simulation are compared to the wind tunnel test results in Figures 4 to 7 for anemometer positions 1, 3, 4 and 5 respectively. While the maximum difference between the wind tunnel and numerical simulations is only of the order of 15%, the numerical simulation appears to have difficulties reproducing the apparent topographic effects and other trends observed in the wind tunnel results. The numerical approach indicates more significant slow down, with all correction factors being less than or equal to unity. In contrast, the wind tunnel results indicate correction factors both greater and less than one.

The most obvious difference in configuring each approach, and perhaps a cause of the differences then, is in the roughness of the land surface, which was modelled as relatively smooth in the CFX model and as a stepped contour model in the physical study.

4. Conclusions

- A 1:400 scale wind tunnel model study of Hong Kong's Waglan Island allowed anemometer position correction factors to be determined. Those factors were in close agreement, both quantitatively and qualitatively, with previously published data.
- Correction factors were used to develop a directional wind speed distribution which was also in good agreement with previously published data.

- A CFD simulation of flow at Waglan Island provided correction factors within 15% of those obtained through physical modelling, although without demonstrating the same apparent trends of the wind tunnel results.
- The effects of model smoothness are deserving of closer scrutiny.

5. References

[1] Buildings Department (HKSAR), Wind tunnel testing of buildings, Practice Note for Authorized Persons and Registered Structural Engineers, PNAP 150.

[2] Chen, T.Y., (1975), Comparison of surface winds in Hong Kong, Royal Observatory, Hong Kong, Technical Note No. 41.

[3] Davenport, A.G., Georgiou, P.N., Mikitiuk, M., Surry, D., Kythe, G., (1984), The wind climate of Hong Kong, Proceedings of the Third International Conference on Tall Buildings, Hong Kong and Guangzhou, pp 454 – 460.

[4] Melbourne, W.H., (1984), Design wind date for Hong Kong and surrounding coastline, Proceedings of the Third International Conference on Tall Buildings, Hong Kong and Guangzhou, pp 461 – 467.

[5] Ng, M.C., (1997), Climatology of Waglan Island 1968 – 1988, Hong Kong Observatory, Technical Note No. 91.

Table 1. Anemometer locations at Waglan Island

Pos	Date Commissioned	Height above MSL (m)	Location
1	1/12/1952	70.1	Weather Observation Building
2	1/1/1964	67.4	Signal Tower
3	12/7/1966	74.7	Signal Tower
4	19/12/1971	74.8	new Instrument Room
5	26/4/1993 to present	82.1	new dedicated mast

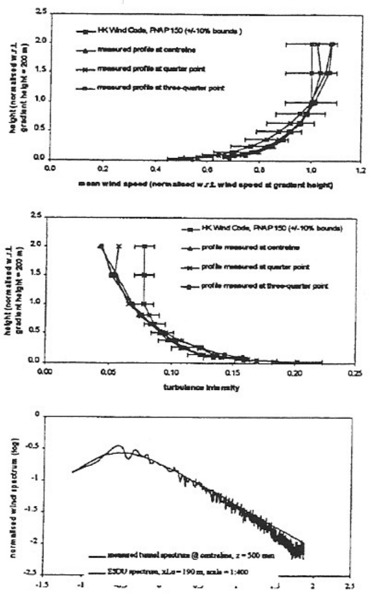

Figure 1: Characteristics of simulated General Terrain

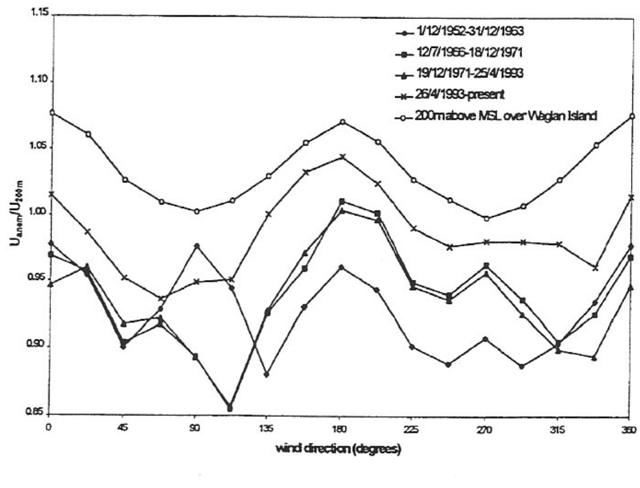

Figure 2: Anemometer correction factors

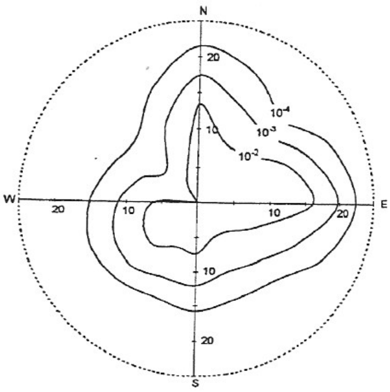

Figure 3a: Probability distribution of directional wind speed, non-typhoon, Waglan Is., 1953-2000

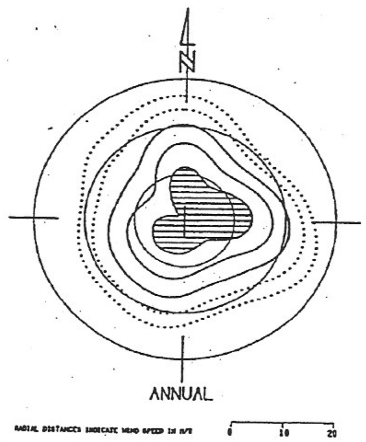

Figure 3b: from Davenport et al. (1984)